

REMARKS

This amendment responds to the Office Action dated June 19, 2001 in which the Examiner objected to claim 13, rejected claims 13 and 15 under 35 U.S.C. § 112, second paragraph, rejected claims 7, 22, 23 and 28 under 35 U.S.C. §102(b), rejected claims 2, 5, 7, 9-11, 14, 15, 17-23 and 28 under 35 U.S.C. §102(e) and rejected claims 1-6, 8-21, 24 and 27 under 35 U.S.C. §103.

As indicated above, a minor informality in claim 13 has been corrected. It is respectfully requested that the Examiner approves the correction and withdraws the objection to claim 13.

As indicated above, claims 13 and 15 have been amended in order to more particularly point out and distinctly claim the subject matter which the applicants regard as the invention. It is respectfully submitted that the rejection of the claims under 35 U.S.C. §112, second paragraph, no longer applies. Therefore, it is respectfully requested that the Examiner withdraws the rejection to the claims under 35 U.S.C. §112, second paragraph.

Claim 1 claims a photomask and claim 16 claims a photomask fabrication method including a transparent substrate, a hollow section formed on the surface of the transparent substrate, a shade pattern formed in the hollow section and reflection preventing sections or films.

Through the structure and method of the claimed invention having reflection preventing sections or films, as claimed in claims 1 and 16, the claimed invention provides a photomask and method of making thereof which has a large mechanical strength and has decreased structural defects in the shade pattern. The prior art does not show, teach or

suggest a photomask and method thereof having reflection preventing sections or films as claimed in claims 1 and 16.

Claim 2 claims a photomask and claim 17 claims a photomask fabrication method in which a shade pattern is formed on a surface on a surface of a transparent substrate and a phase shift pattern, a surface of which is planarized by chemical and mechanical polishing, is selectively formed on the shade pattern and the transparent substrate.

Through the structure and method of the claimed invention forming a shade pattern on the surface of a transparent substrate and forming a planarized phase shift pattern by chemical and mechanical polishing, as claimed in claims 2 and 17, the claimed invention provides a photomask and fabrication method thereof in which a phase shift pattern has a uniform thickness so that the contrast of an optical image is increased. The prior art does not show, teach or suggest a shade pattern formed on a surface of a transparent substrate or a phase shift pattern planarized by chemical and mechanical polishing as claimed in claims 2 and 17.

Claim 5 claims a photomask and claim 20 claims a photomask fabrication method in which a shade pattern is formed in a hollow section of a transparent substrate and a phase shift pattern, which is planarized, is selectively formed on the transparent substrate and part of the shade pattern.

Thus, the claimed invention provides a photomask and a fabrication method thereof in which it is possible to increase the contrast of an optical image when semiconductor integrated circuits are fabricated using the phase shift photomask. The prior art does not show, teach or suggest the invention as claimed in claims 5 and 20.

Claim 7 claims a photomask and claim 22 claims a photomask fabrication method in which a phase shift pattern is formed in a transparent substrate.

Thus, the claimed invention provides a photomask and fabrication method thereof in which it is possible to increase the contrast of an optical image when the photomask is used. The prior art does not show, teach or suggest forming a phase shift pattern in the substrate itself as claimed in claims 7 and 22.

Claim 28 claims a photomask comprising a transparent substrate, a hollow section and a shade pattern including a shade section formed in the hollow section. The surface of the transparent substrate and the shade pattern are planarized to form a same surface.

Through the structure of the claimed invention having a photomask without a phase shifter, as claimed in claim 28, the claimed invention provides a photomask in which there is no mechanical stress that occurs during the washing process which increases the yield. The prior art does not show, teach or suggest a photomask as claimed in claim 28.

Claims 7, 22, 23 and 28 were rejected under 35 U.S.C. §102(b) as being anticipated by *Hur et al* (U.S. Patent No. 5,437,947).

Applicant respectfully traverses the Examiner's rejection of the claims under 35 U.S.C. §102(b). The claims have been reviewed in light of the Office Action, and for reasons which will be set forth below, it is respectfully requested that the Examiner withdraws the rejection to the claims and allows the claims to issue.

Hur et al appears to disclose a phase shifting mask in which a transparent substrate 21 is coated with a layer of photoresist material 22 and then a photoresist pattern is formed. With the pattern photoresist layer 22 as a mask, the revealed substrate 21 is

etched to form a trench 23. Upon removal of the photoresist layer 22, a layer of chrome 24 is deposited over the substrate 21. The layer of chrome 24 is etched back and then an opaque layer remains in the trench 23. A layer of oxide 26 with a layer of photoresist material 27 thereon is formed. The photoresist layer 27 is patterned and the oxide layer 26 is exposed at the portion corresponding to the partially removed photoresist layer. With the pattern photoresist layer 27 as a mask, the exposed oxide layer 26 is etched away to form a phase shift mask 28 over the substrate 21 which remains unetched between the trenches and then the photoresist layer is removed. (Col 3, lines 20-51). In Figures 5A to 5H, after the phase shifting layer 28 is formed, the quartz substrate 21 underneath the phase shifting layer 28 is etched. The phase shifting layer 28 and opaque layer 25 serve as the dry etch mask to form a groove on both sides of the trench 23. The quartz substrate 21 is etched to the optimize thickness for maximizing the light sensitivity. (Col 4, lines 32-47). FIG. 9A and 9F are the process steps of the mask in which the transparent quartz substrate 21 is coated the photoresist film 22 to form the photoresist pattern of width W through the well-known photolithographic process (FIG. 9A). The patterned photoresist film 22 acts as the mask to form a trench 23 by etching the substrate 21 (FIG. 9B). Upon removal of the photoresist pattern 22, a layer of chrome 24 is deposited over the substrate 21 to fully fill the trench 23 (FIG. 9C). The physical and chemical polishing step makes the opaque layer 25 as high as the quartz substrate, thereby maintaining the smoothed level throughout the whole surface for planarization (FIG. 9D). Over the entire surface it is formed an oxide layer 26 on which a photoresist film is coated again. The coated photoresist film 27 is patterned to form a photoresist pattern by photolithography (FIG.

9E). Upon removal of the photoresist layer 27 after the formation of the phase shifting layer, it is obtained the edge enhancement phase shifting mask of the full filled trench with the opaque layer. (Col 5, lines 2-24).

Thus, *Hur et al* discloses in FIGs. 9A-9F an oxide layer 26, which is formed on the entire surface of the substrate 21, formed into a phase shifting layer 28. Thus, nothing in *Hur et al* shows, teaches or suggests a phase shift pattern formed in the transparent substrate or that the phase shift pattern is formed by a hollow section as claimed in claim 7. Rather, in *Hur et al* the oxide layer that is formed into the phase shift pattern 28 is formed on top of the transparent substrate.

Additionally, since *Hur et al* discloses in Figs. 9A-9F that the phase shift pattern 28 is formed by first depositing an oxide and then a resist layer 27, nothing in *Hur et al* shows, teaches or suggests that after a shade pattern is formed, selectively etching the transparent substrate to form the phase shift pattern as claimed in claim 22. Rather, *Hur et al* merely discloses that only the oxide layer, which is formed on the substrate 21, is etched into the phase shift pattern 28.

Similarly, FIG. 5 of *Hur et al* merely discloses forming the phase shift layer 28 on top of the transparent substrate 21 and then forming a groove in both sides of a trench 23. Thus, nothing in *Hur et al* shows, teaches or suggests that the phase shift pattern is formed in the transparent substrate as claimed in claim 7. Rather, the phase shift layer 28 of *Hur et al* is formed on top of the substrate, while the groove is used to denote the thickness of the phase shift layer.

Furthermore, in FIG. 5 of *Hur et al*, the opaque layer 25 is never chemically and mechanically polished to form a shade pattern as claimed in claim 22. Similarly, the transparent substrate in Fig. 5 of *Hur et al* is not etched to form the phase shift pattern but the phase shift pattern is formed by the oxide layer 26. Thus, nothing in *Hur et al* shows, teaches or suggests the invention as claimed in claim 22.

Finally, *Hur et al* is merely directed to forming a phase shifting mask. Thus, nothing in *Hur et al* shows, teaches or suggests a photomask (without a phase shifting layer) as claimed in claim 28. Rather, *Hur et al* does not show, teach or suggest how to form a photomask without a phase shifting layer.

Since nothing in *Hur et al* shows, teaches or suggests the invention as claimed in claims 7, 22 and 28 as discussed above, it is respectfully requested that the Examiner withdraws the rejection to claims 7, 22 and 28 under 35 U.S.C. §102(b).

Claim 23 depends from claim 22 and recites additional features. It is respectfully submitted that claim 23 would not have been anticipated by *Hur et al* within the meaning of 35 U.S.C. §102(b) at least for the reasons as set forth above. Therefore, it is respectfully requested that the Examiner withdraws the rejection to claim 23 under 35 U.S.C. §102(b).

Claims 2, 5, 7, 9-11, 14, 15, 17-23 and 28 were rejected under 35 U.S.C. §102(e) as being anticipated by *Lee* (U.S. Patent No. 5,824,439).

Applicant respectfully traverses the Examiner's rejections of claims under 35 U.S.C. § 102(e). The claims have been reviewed in light of the Office Action and for reasons which are set forth below, it is respectfully requested that the Examiner withdraws the rejection to the claims and allows the claims to issue.

Lee '439 appears to disclose referring to FIG. 1D, the light-shading layer 13 is etched using an etchant so that the light-shading layer 13 is etched in a sideward direction. As a result, the lower part of the phase shifting layer 17 is undercut. Here, the undercut part of the phase shifting layer becomes a phase shifting region and the part which is in contact with the light-shading layer 13 becomes a light-shading region. A part where the phase shifting layer 17 is not formed is a light-transmission region. (Col 2, lines 1-8)

FIG. 3 is a cross-sectional view of a phase shifting mask. As shown in FIG. 3, a groove 37 is formed on a predetermined region of a transparent substrate 31 made of a transparent material, e.g., soda lime glass or quartz. A light-shading layer 39 is formed within the groove 37. The phase shifting layer 41 is formed so as to be in contact with the transparent substrate 31 at both sides of the groove 37, thereby limiting the light-shading layer 39 to be within the groove 37. (Col 4, lines 3-24, Col 5, lines 43-47). FIGS. 4A-4D show a method of manufacturing a phase shifting mask in which a transparent substrate 31 has a sacrificial layer 33 formed thereon. The sacrificial layer 33 is patterned to expose a predetermined portion of the substrate 31. Sidewalls 35 are formed on the sides of the sacrificial layer. Using the sacrificial layer 33 and sidewalls 35 as a mask, the exposed region of the substrate 31 is etched to form a groove 37. The sidewalls 35 are removed and then, on the sacrificial layer 31 and the exposed region of the substrate 31, Zn or polycrystalline silicon is deposited to fill the groove 37. Then through a chemical mechanical polishing method, zinc or a polycrystalline silicon on the sacrificial layer 33 and the transparent substrate is polished to expose the sacrificial layer 33 and planarized. Oxygen ions are implanted into the zinc or polycrystalline silicon and heat-treated, or heat

is applied to oxidize the zinc or polycrystalline silicon thereby forming a phase shifting layer 41. The part of the zinc or polycrystalline silicon that is not oxidized is defined as a light-shading layer 39. (Col. 5, lines 6-43).

Thus, *Lee* merely discloses a light-shading layer 39 formed within a groove 37. Nothing in *Lee* shows, teaches or suggests a shade pattern formed on a surface of the transparent substrate as claimed in claims 2 and 17. Rather, *Lee* teaches away from the claimed invention and forms the shading layer 39 within a groove 37.

Furthermore, *Lee* merely discloses polishing a zinc or polycrystalline silicon on the sacrificial layer to expose the sacrificial layer. Nothing in *Lee* shows, teaches or suggest performing a chemical and mechanical polishing for a surface of a phase shift pattern to form a desired thickness as claimed in claim 17 or planarizing a surface of a phase shift pattern as claimed in claim 2. *Lee* merely discloses exposing a sacrificial layer.

Additionally, *Lee* discloses that the phase shifting layer 41 is formed so as to be in contact with the transparent substrate 31 at both sides of the groove 37. Thus, nothing in *Lee* shows, teaches or suggests a phase shift pattern, which is planarized, selectively formed on the transparent substrate and part of the shade pattern as claimed in claim 5. Rather, *Lee* teaches away from the claimed invention and forms the phase shifting layer 41 completely over the light-shading layer 39.

Additionally, since the phase shifting layer 41 is formed on top of the substrate 31, nothing in *Lee* shows, teaches or suggests that the phase shift pattern is formed in the transparent substrate as claimed in claim 7 or that the transparent substrate is selectively etched to form the phase shift pattern as claimed in claim 22. Rather, *Lee* teaches away

from the claimed invention since the phase shifting layer 41 is formed on top of the substrate 31 and not in the substrate.

Furthermore, *Lee* clearly discloses filling the groove with zinc or a polycrystalline silicon and then polishing the zinc or polycrystalline silicon and the sacrificial layer and the transparent substrate to expose the sacrificial layer 33 and planarize. Thus, nothing in *Lee* shows, teaches or suggests that the resist film is eliminated from the transparent substrate prior to forming the shade film in the hollow sections or a planarized phase shift pattern as claimed in claim 20. Rather, *Lee* teaches away from the claimed invention and forms the zinc or polycrystalline silicon over the sacrificial layer 33.

Finally, *Lee* merely discloses a method of manufacturing a phase shifting mask and the phase shifting mask. Thus, nothing in *Lee* shows, teaches or suggests a photomask (without a phase shifting layer) as claimed in claim 28.

Since nothing in *Lee* shows, teaches or suggests the invention as claimed in claims 2, 5, 7, 17, 20, 22 and 28 as discussed above, it is respectfully requested that the Examiner withdraws the rejection to claims 2, 5, 7, 17, 20, 22 and 28 under 35 U.S.C. §102(e).

Claims 9-11, 14, 15, 18-19, 21 and 23 depend from claims 2, 17, 20 and 22 and recite additional features. It is respectfully submitted that the claims would not have been anticipated by *Lee* within the meaning of 35 U.S.C. §102(e) at least for the reasons as set forth above. Therefore, it is respectfully requested that the Examiner withdraws the rejection to claims 9-11, 14, 15, 18-19, 21 and 23 under 35 U.S.C. §102(e).

Claims 2, 5, 9-11, 14, 15 and 17-21 were rejected under 35 U.S.C. §103 as being unpatentable over *Hur et al* in view of *Lee '439*.

Applicant respectfully traverses the Examiner's rejection of the claims under 35 U.S.C. §103. The claims have been reviewed in light of the Office Action, and for reasons which will be set forth below, it is respectfully requested that the Examiner withdraws the rejection to the claims and allows the claims to issue.

As discussed above, nothing in *Hur et al* or *Lee* shows, teaches or suggests a shade pattern formed on a surface of a transparent substrate as claimed in claims 2 and 17. *Hur et al* clearly discloses that the opaque layer 25 is formed in a trench and thus is not formed on the surface of the substrate. Similarly, the light shading layer 39 in *Lee* is formed inside the groove 37. Thus, nothing in *Hur et al* or *Lee* shows, teaches or suggests a shade pattern formed on the surface of a transparent substrate as claimed in claims 2 and 17. Furthermore, nothing in *Hur et al* or *Lee* shows, teaches or suggests performing a chemical and mechanical polishing for a surface of a phase shift pattern to a desired thickness as claimed in claim 17 or planarizing a surface of a phase shift pattern as claimed in claim 2.

Additionally, *Hur et al* discloses in FIG. 9F that the phase shift pattern is formed completely over the opaque layer 25 while in FIGs. 5 the phase shift pattern 28 is formed only over the substrate 21. Thus, nothing in *Hur et al* shows, teaches or suggests a phase shift pattern, which is planarized, formed on the transparent substrate and part of the shade pattern as claimed in claim 5. Similarly, FIGs. 4 of *Lee* also disclose that the phase shift pattern is formed to cover the light shading layer 39 in the groove 37. Thus, nothing in *Lee* shows, teaches or suggests the phase shift pattern, which is planarized, formed on the substrate and part of the shade pattern as claimed in claim 5.

Finally, *Hur et al* merely discloses in FIGs. 9 that an oxide layer 26 is patterned by a photoresist film 27. Thus, nothing in *Hur et al* shows, teaches or suggests forming a planarized phase shift pattern as claimed in claim 20. Furthermore, *Lee* merely discloses that a zinc or polycrystalline silicon layer is planarized, then ion implanted and heat treated to form the phase shifting layer 41. Thus, no phase shift film is formed which is then selectively etched to form a planarized phase shift pattern as claimed in claim 20. Rather, a layer is formed which will become a light-shading layer or a phase shifting layer depending upon whether ion atoms can be properly implanted and heat treated in *Lee*. Thus, the planarization in *Lee* takes place prior to forming the phase shifting film and is not done by etching as claimed in claim 20.

Since nothing in the combination of *Hur et al* and *Lee* shows, teaches or suggests the invention as claimed in claims 2, 5, 17 and 20 as discussed above, it is respectfully requested that the Examiner withdraws the rejection to claims 2, 5, 17 and 20 under 35 U.S.C. §103.

Claims 9-11, 14, 15, 18-19 and 21 depend from claims 2, 17 and 20 and recite additional features. It is respectfully submitted that claims 9-11, 14, 15, 18-19 and 21 would not have been obvious within the meaning of 35 U.S.C. §103 over *Hur et al* and *Lee* at least for the reasons as set forth above. Therefore, it is respectfully requested that the Examiner withdraws the rejection to claims 9-11, 14, 15, 18-19 and 21 under 35 U.S.C. §103.

Claim 1 was rejected under 35 U.S.C. §103 as being unpatentable over *Hur et al* or *Lee '439* in view of *Tanabe* (U.S. Patent No. 5,945,237).

In addition, claims 16 and 24 were rejected under 35 U.S.C. §103 as being unpatentable over *Hur et al* or *Lee '439* in view of *Tanabe* and further in view of *Mitsui* (U.S. Patent No. 6,037,083).

Applicant respectfully traverses the Examiner's rejection of the claims under 35 U.S.C. §103. The claims have been reviewed in light of the Office Action, and for reasons which will be set forth below, it is respectfully requested that the Examiner withdraws the rejection to the claims and allows the claims to issue.

As discussed above, both *Hur et al* and *Lee* are directed to a phase shifting mask and method of manufacturing thereof. Thus, nothing in *Hur et al* or *Lee* shows, teaches or suggests a photomask (without a phase shifter) as claimed in claims 1 and 16. Furthermore, neither *Hur et al* nor *Lee* shows, teaches or suggests reflection preventing sections as claimed in claims 1 and 16.

Tanabe appears to disclose in a halftone phase-shift mask, a phase-inverting light transmission part is formed inside the light-blocking part which blocks light that is radiated onto a transparent substrate so as to cover a shifter missing part defect, this phase-inverting light transmission part inverting the phase of light that passes through it with respect to light that passes through a light transmission part.

Thus, *Tanabe* similarly discloses a phase-shift mask. Nothing in *Tanabe* shows, teaches or suggests a photomask (without a phase shifter) as claimed in claims 1 and 16.

Additionally, *Tanabe* merely discloses a single or multi-layer film made of chrome oxide. However, nothing in *Tanabe* shows, teaches or suggests that a reflection preventing film formed on a shade section, a reflection preventing film formed under a shade section

or a reflection preventing film formed on and under a shade section as claimed in claim 1 and claim 16.

Mitsui appears to disclose acid-resistant, highly reliable phase shift masks, and phase shift mask blanks, wherewith high-precision patterning is possible. A halftone phase shift mask blank comprising a transparent substrate 10, a halftone material film 11 laminated on that transparent substrate, and a metal film 12 laminated on that halftone material film, wherein the metal film is formed by a plurality of metal films having different etching rates, and the etching rate for the metal film positioned on the transparent substrate side is set so that it is faster, either in stages or continuously, than the etching rate of the metal film positioned on the surface side.

Thus, *Mitsui* similarly discloses a phase shift mask and does not show, teach or suggest a photomask (without a phase shifter) as claimed in claims 1 and 16.

Furthermore, *Mitsui* merely discloses a metal film formed of a plurality of layers. Thus, nothing in *Mitsui* shows, teaches or suggests a reflection preventing section formed on and under a shade section as claimed in claim 16.

Attached to this amendment is a description of a difference between a phase shift film, a half-tone film and reflection preventing film, each of which is optically different from each other and which are never confused by a person of ordinary skill in the art.

Since nothing in *Hur et al*, *Lee*, *Tanabe* or *Mitsui* shows, teaches or suggests a photomask (without a phase shifter) or the reflection preventing section placement as claimed in claims 1 and 16, it is respectfully requested that the Examiner withdraws the rejection to claims 1 and 16 under 35 U.S.C. §103.

Claim 24 depends from claim 16 and recites additional features. It is respectfully submitted that claim 24 would not have been obvious within the meaning of 35 U.S.C. §103 at least for the reasons as set forth above. Therefore, it is respectfully requested that the Examiner withdraws the rejection to claim 24 under 35 U.S.C. §103.

Claims 3, 4, 6, 8, 12, 13 and 27 were rejected under 35 U.S.C. §103 over various references. It is respectfully submitted that since the primary references do not disclose the features as discussed above, the combination with the secondary references would not overcome the deficiencies of the primary references. Therefore, it is respectfully requested that the Examiner withdraws the rejection to claims 3, 4, 6, 8, 12, 13 and 27 under 35 U.S.C. §103.

Thus it now appears that the application is in condition for reconsideration and allowance. Reconsideration and allowance at an early date are respectfully requested.

If for any reason the Examiner feels that the application is not now in condition for allowance, it is respectfully requested that the Examiner contact, by telephone, the Applicant's undersigned attorney at the indicated telephone number to arrange for an interview to expedite the disposition of this case.

In the event that this paper is not timely filed within the currently set shortened statutory period, Applicant respectfully petitions for an appropriate extension of time. The fees for such extension of time may be charged to our Deposit Account No. 02-4800.

In the event that any additional fees are due with this paper, please charge our Deposit Account No. 02-4800.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: 

Ellen Marcie Emas
Registration No. 32,131

P.O. Box 1404
Alexandria, Virginia 22313-1404
(703) 836-6620

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Marked-up Claims 5, 7, 13, 15 and 22

5. (Twice Amended) A photomask comprising:
- a transparent substrate;
 - a hollow section formed on a surface of said transparent substrate;
 - a shade pattern made up of a shade film, said shade film formed in said hollow section; and
 - a phase shift pattern whose surface is planarized, selectively formed on said transparent substrate [having] and part of said shade pattern formed in said hollow section.
7. (Thrice Amended) A photomask comprising:
- a transparent substrate;
 - a hollow section formed on a surface of said transparent substrate;
 - a shade pattern made up of a shade film, said shade film formed in said hollow section; and
 - a phase shift pattern formed [by etching] in said transparent substrate [including said shade pattern formed in said] by another hollow section.
13. (Twice Amended) A photomask [according to claim 2, wherein said phase shift pattern includes a phase shift pattern having a mask pattern formed with a half time film having a low transmissivity in reverse phase and a shade pattern is applied to a large area section] comprising:
- a transparent substrate; and

Marked-up Claims 5, 7, 13, 15 and 22

a halftone phase shift pattern selectively formed on said transparent substrate,
wherein a surface of said phase pattern is flat.

15. (Twice Amended) A photomask [according to claim 2, wherein said phase shift pattern includes a phase shift pattern having a shade pattern formed with a phase shifter and the shade pattern is applied to a large area section] comprising:

a transparent substrate; and
an intermediate type phase shift pattern selectively formed on said transparent
substrate,

wherein a surface of said phase shift pattern is flat.

22. (Amended) A photomask fabrication method comprising the steps of:
forming a resist film on a transparent substrate;
forming a desired pattern on said resist film by developing said resist film after said resist film is selectively exposed by using a radiation ray;
forming hollow sections in said transparent substrate by selectively etching said transparent substrate by using said resist film as a mask;
eliminating said resist film from said transparent substrate;
forming a shade film in each of said hollow sections;
performing a chemical and mechanical polishing for said shade film in order to form a shade pattern;

Marked-up Claims 5, 7, 13, 15 and 22

forming a resist film on said transparent substrate in which said shade pattern has been formed;

selectively etching said resist film by using said radiation ray; and

selectively etching said transparent substrate to form a phase shift pattern in the transparent substrate.

Comparison of 1. phase shift film, 2. half tone film and 3. antireflection film

1. phase shift condition

$$d1 = \lambda / 2 (n1 - 1)$$

$$t1 = 100\%$$

2. half tone phase shift condition

$$d2 = \lambda / 2 (n2 - 1)$$

$$t2 = 5 \sim 20\%$$

3. antireflection condition

$$d3 = \lambda / 4 n3$$

$$t3 = \sim 50\%$$

λ : wavelength

$n0$: refractive index of shade film

$n1$: refractive index of phase shift film

$n2$: refractive index of half tone film

$n3$: refraction index of antireflection film

$d1$: thickness of phase shift film

$d2$: thickness of half tone film

$d3$: thickness of antireflection film

$t1$: transmittance of phase shift film

$t2$: transmittance of half tone film

$t3$: transmittance of antireflection film

